FINAL STAFF REPORT

VENTURA COUNTY

AIR POLLUTION CONTROL DISTRICT
RULE 74.15.1, EMISSIONS of OXIDES of NITROGEN from SMALL INDUSTRIAL, INSTITUTIONAL, and COMMERCIAL BOILERS, STEAM GENERATORS, and PROCESS HEATERS

MAY 4,1993

EXECUTIVE SUMMARY

The District developed Rule 74.15.1 to control oxides of nitrogen (NOx) emissions from boilers, steam generators, and process heaters with heat input rating from 1 million Btu (MMBtu) to less than 5 MMBtu. Staff estimates that there are 175 such boilers, steam generators, and process heaters within the District.

Staff modeled Rule 74.15.1 after Rule 74.15, which requires controls to reduce NOx emissions from boilers, steam generators, and process heaters with heat input rating equal to or greater than 5 MMBtu. A significant difference between the two rules is the emission limit. Rule 74.15 places a NOx emission limit of 40 parts per million volume (ppmv) on boilers subject to that rule. District staff is proposing a 30 ppmv NOx emission limit for small boilers and heaters. There are currently several manufacturers of replacement burners for small boilers who have displayed emissions well below the 30 ppmv limit. These burners are less expensive than the previous technology which met the 40 ppmv limit. The rule specifies a compliance date of May 31, 1995.

The NOx emission limit will require retrofitting affected boilers and heaters using emission controls such as low-NOX burners, flue gas recirculation, 0_2 trim, and clean fuels.

There are about 175 units known to District staff with a gross heat input between 1 and 5 MMBtu per hour. Based on an engineering estimate of 5.5 x 10^9 Btu per year consumed by each unit, these units currently emit 96.25 tons of NOx per year. Implementation of Rule 74.15.1 will result in an emission reduction from controlled units of about 64.73 tons of NOx per year plus an additional emission reduction of 3.45 tons of NOx per year due to the tune-ups imposed on the balance of the units.

Discussions with manufacturer representatives, who perform the boiler retrofits, indicate the minimum fuel savings resulting from installing new, fuel efficient burners is ten percent. The boiler operator will have the option of installing an external flue gas recirculation system that would result in no fuel savings. However, there are fuel efficient options available for both atmospheric burners and forced-draft burners. The cost-effectiveness for a 3.0 MMBtu unit with an atmospheric burner retrofit with a low-NOX burner is a savings of $2,462.61 per ton (savings of $1.23 per pound) of NOx reduced with an annualized savings of $1,103.99.

The cost-effectiveness for a 3.0 MMBtu unit with a forced-draft burner is $10,459.65 per ton ($5.23 per pound) of NOx reduced. The annualized cost is $1,918.30. If the owner adds external flue gas recirculation, the cost-effectiveness is $32,951.07 per ton ($16.48 per pound) of NOx reduced. The annualized cost is $5,710.42.

The rule provides an exemption from the 30 ppmv NOx emission limit for about 99 units with an annual heat input of less than 1.8 x 10^9 Btu. These units can comply by:

- Installing a nonresetting, totalizing fuel meter to prove exemption status and having semiannual tune-ups; or
- Meeting the 30 ppmv NOx emission limit.

Units would have a one-time cost of approximately $1,800.00 for a fuel meter. If Southern California Gas Company will provide the necessary reports, District policy is to accept Southern California Gas Company tune-ups as meeting the tune-up requirement.

There are a few units, mainly standby units, with an <u>annual</u> heat input of less than 0.3 x 10^9 Btu. These units would be required to install a nonresetting, totalizing fuel meter and maintain monthly records to prove exemption status. However, the units would be exempt from any

requirement for semiannual tune-up or compliance with the 30 ppmv emission limit.

The worst case cost-effectiveness for a forced-draft burner; a cost of $100,547.80 per ton ($50.27 per pound) of NOx reduced; would occur if external flue gas recirculation was installed on a 2 MMBtu unit using 1.8 x 10^9 Btu of fuel per year. However, according to the information available on forceddraft units, there are none with utilization that low. The initial installation costs are too high for a unit that would only be used infrequently.

The adoption of Rule 74.15.1, Emissions of Oxides of Nitrogen From Small Industrial, Institutional, and Commercial Boilers, Steam Generators, and Process Heaters, will implement Control Measure N-105, Attachment A, of the *1991 Air Quality Management Plan.* The rule will affect all operators of boilers in the I MMBtu to 5 MMBtu heat input range by requiring either rule compliance or installation of a fuel meter and monthly recordkeeping of fuel consumption. Also, dual fired units would require daily recordkeeping when operating on alternate fuel.

Adopting Rule 74.15.1 establishes BACT for small boilers. All new units in the heat input rating range covered by the rule will be required to meet the emission limits in the rule. Also, replacement burners in those units currently exempt from the rule will be required to meet the emission limits in the rule. The result will be additional NOx emission reductions for the District.

BACKGROUND

AFFECTED INDUSTRIES

Staff has identified approximately 175 boilers, heaters, and steam generators that are subject to Rule 74.15.1. Many commercial, industrial, and public entities use small boilers, heaters, and steam generators to provide steam or hot water for comfort heating, domestic hot water, pool heating or as a part of the industrial process. Attachment B provides a listing of affected industries.

Employment

As shown in Attachment B, most areas of employment, listed in the California Employment Development Department (EDD) publication "Projections of Employment by Industry and Occupation," potentially use a boiler, steam generator, or process heater as part of day to day operations. If compliance with the rule requirements placed an excessive financial burden on the boiler owner/operator, there would be a potentially negative impact on employment. However, the control technology for rule compliance is not only readily available but will mostly generate a savings for the boiler owner/ operator. Therefore, the major impact on employment will be positive as workers will be hired to install the new equipment on the boilers.

OXIDES OF NITROGEN

Combustion equipment collectively represents the largest nonvehicular source of oxides of nitrogen air contaminants in most industrial areas. In Ventura County, where there is a high motor vehicle density, boilers and heaters are still responsible for about 40 percent of the total NOx discharged to the atmosphere and for about 60 percent from all stationary sources. Small gas fired heaters account for 20 to 25 percent of the total boiler and heater emissions.

Emissions of NOx from combustion equipment result from fixation of atmospheric nitrogen in the burner primary flame zone. The principal high temperature reaction is the formation of nitric oxide. The reaction depends upon high temperatures. Much of the nitric oxide is eventually further oxidized to nitrogen dioxide. The nitrogen dioxide conversion reaches a maximum at 60^oF and is extremely slow at ambient temperature. Nitrogen dioxide is considerably more reactive than nitric oxide, and is a more noxious air contaminant.

The reaction also forms several other oxides of nitrogen to lesser degrees. These oxides include N_20, N_20_4, N_20_5, and $N0_3$ but the emissions are insignificant. For purposes of this discussion, staff terms all oxides of nitrogen, NOx. In the quantitative analysis of oxides of nitrogen, all oxides commonly oxidize to the dioxide. Staff reports concentrations of NOx as NO_2.

Mixing of the fuel and air begins in turbulent zones close to the burner, and combustion occurs only when the turbulent eddy mixture ratio is close to stoichiometric. Because combustion is extremely rapid, the temperature increases to adiabatic flame temperature (no heat loss). The NO formation begins with the onset of combustion as the gas products expand into the furnace. The amount of NO formed depends upon the subsequent temperature and concentration history of the combustion products with time. Temperature decay of the combustion products results from mixing with the colder bulk gas recirculating in the flame zone. As the temperature decreases, the NO formation rate falls off. Small. boilers and steam generators operate at a much lower temperature than large combustion units. This is the primary reason for the lower NOx generation.

BOILERS, HEATERS, AND STEAM GENERATORS

Commerce and industry uses boilers, heaters, steam generators, and similar combustion equipment fired with fossil fuels to transfer heat from combustion gases to water or other fluids. The only significant emissions to the atmosphere from this equipment in normal operation, whatever the fluid heated or vaporized, are those resulting from the burning of fossil fuels. Differences in design and operation of this equipment can affect production of air contaminants. One major design/operation criteria affecting the production of NOx is the burner. Burners, although different in appearance, are essentially of two types; atmospheric and forced-draft.

A boiler or heater consists essentially of a burner, firebox, heat exchanger, and a means of creating and directing a flow of gases through the unit. All combustion equipment, from the smallest domestic water heater to the largest power plant steam generator, includes these essentials.

Burners

A burner is essentially a triggering mechanism used to ignite and oxidize hydrocarbon fuels. Burner design and operation push the oxidation reactions as close as possible to completion. This causes maximum production of carbon dioxide and water and minimum unburned and partially oxidized compounds in exhaust gases. Burner efficiency can be measured by the water and carbon dioxide contents of the combustion gases or, conversely, by the concentrations of carbon monoxide, carbon, aldehydes, and other oxidizable compounds. For hydrocarbon-derived pollutants, optimum burner operation goes hand in hand with minimum air pollution.

All combustion equipment requires some energy to push or pull, the combustion air, fuel, or products of combustion through the burner and through the heat exchanger.

With small gas-fired appliances, the line gas pressure with the buoyancy of warm oxidation products is sufficient to provide the necessary draft. These small appliances and larger equipment with extended natural draft stacks have atmospheric burners.

If a blower pushes or pulls; the combustion air, fuel, or products of combustion through the burner and through the heat exchanger, the burner is forceddraft. The blower may be positioned ahead of or behind the firebox. When located ahead of the firebox, a blower is sometimes an integral part of the burner and the drive motor is common to a fuel pump or atomizing device. Forced-draft burners provide greater flexibility and can be used in situations where the firebox itself is under pressure.

The forced-draft burner provides better combustion than an atmospheric burner resulting in lower emissions from existing units. Therefore, the emission factor for forced-draft units is 80 ppm NOx and the emission factor for atmospheric burners is 160 ppm NOx.

Industrial Boilers and Water Heaters

Most combustion equipment is used to heat or vaporize water, or both. For convenience, staff combines industrial water heaters with boilers since identical equipment is used for both purposes. These boilers and heaters fall into three general classifications: Fire tube, water tube, and sectional.

Fire tube boilers make up the largest share of small and medium size industrial units. In fire tube boilers, the products of combustion pass through the heat exchanger tubes, while water, steam, or other fluid is contained outside the tubes. Many boilers such as these are sold as packaged units, with burners, blowers, pumps, and other auxiliaries all mounted on the same framework.

Water tube boilers are constructed in a wide range of sizes. Both the smallest and largest industrial units are likely to be of water tube design. All large boilers (steam generators) are of this type.

The smallest units are of simple box construction, commonly using tubing to circulate water and steam. In the water tube design, fluid is heated under pressure in a coil heat exchanger and flashed into steam in an external chamber. These small, controlled circulation boilers can produce steam within minutes after a cold start. Industrial water tube boilers are usually constructed with comparatively larger fireboxes than fire tube boilers have. In all water tube boilers, the water, steam, or heat transfer medium is circulated through the tubes while hot products of combustion pass outside the tubes.

Sectional boilers employ irregularly shaped heat exchangers and cannot be classed as either water tube or fire tube. Hot combustion gases are directed through some of these passages, transferring heat through metal walls, to water or steam in the other passages. These units are manufactured in identical sections that can be joined according to the needs of the operator. A sectional boiler consists of one or more sections and can be enlarged or reduced by adding or removing sections. The heat exchanger assemblies are usually fabricated of cast iron. Consequently these boilers are not suitable for pressures greatly exceeding 15 psig. Cast iron sectional boilers find frequent use as water heaters and steam generators used with space heating and laundries.

RULE REQUIREMENTS

The rule is based on Rule 74.15. Rule 74.15 places emission control requirements on boilers, steam generators, and process heaters with a heat input rating of 5 MMBtu or greater. The rule applies to all boilers, steam generators, and process heaters with a heat input rating of greater than 1 MMBtu but less than 5 MMBtu. Many small users will not be required to either retrofit their unit(s) with low-NOX burners or install emission control equipment. Following is a discussion of the main elements of Rule 74.15.1 that are summarized in Table 1.

EMISSION REDUCTIONS

The primary requirement of the rule is a NOx emission limit of either less than 30 ppmv. The business owner/operator can select the method of meeting the required emission limits.

Flue Gas Recirculation

This technique lowers the peak flame temperature by diluting the primary flame zone with recirculated combustion flue gases. The technique lowers oxygen concentration. The combination of lower peak flame temperature and reduced oxygen concentration reduces NOx emissions.

Low-NOX Burners

Several manufacturers market burners with NOx emissions below the required limit of 30 ppmv. The processes used are not identical; however, there is a commonality of premixing fuel and air before combustion and operation at lower temperatures.

RECORDKEEPING

Monthly records of fuel consumption must be maintained by all persons subject to the rule. If a person claims exemption from the emission limitation requirements, that person must maintain monthly records showing compliance with exemption requirements.

Also, if a unit operates on alternate fuel, the operator must maintain daily records of type of fuel, fuel consumption, and duration of operation.

Table 1
Rule 74.15.1, Boilers, Steam Generators, and Process Heaters

Requirements
1. Emission Limits - Annual heat input equal to or greater than 1.8 x 10^9 Btu
   - Limit the discharge into the atmosphere oxides of nitrogen (NOx) emissions to less than 30 ppmv-, and
   - Limit carbon monoxide (CO) emissions to less than 400 ppmv.
2. Exempt from Emission Limits - Annual heat input less than 1.8 x 10^9 Btu
   - Option 1
     - Install fuel totalizing meter
     - Annual heat input equal to or greater than 03 x 10^9 Btu
     - Tune the unit at least once per calendar year
   - Option 2
     - Comply with the 30 ppmv emission limit

Exemptions
1. Alternate fuel

Administrative Requirements
1. Monthly Records of fuel consumption for exempt units
2. Tune-up results submitted to APCO.
3. Daily Records
   - Alternate fuel, each occurrence.
   - Type of fuel
   - Quantity of fuel
   - Duration of the occurrence
4. Fuel consumption records and alternate fuel records shall be maintained for four (4) years

Test Methods - Stack Gas Oxygen - ARB Method 100

CONTROL TECHNOLOGY

There are several options available for controlling NOx emissions from boilers, steam generators, and process heaters; however, the costs associated with some control methods are prohibitively expensive. The discussion below is limited to those control methods that provide a cost/benefit ratio that meets the District's guidelines for cost-effectiveness.

EMISSION CONTROL TECHNIQUES

The NOx emission control techniques for the Rule 74.15.1 - Emissions of Oxides of Nitrogen From Small Industrial, Institutional, and Commercial Boilers, Steam Generators, and Process Heaters include the following:

Low-NOX Burners

Burners designed to control the combustion process with controlled air/fuel mixing and increased heat dissipation to minimize NOx formation. The low-NOX burners for atmospheric boilers actually prevent the formation of NOx. The low-NOX burners for forced-draft units use a portion of the flue gas in a staged combustion process to decrease NOx emissions.

Flue Gas Recirculation (FGR)

Combustion modification that involves introducing part of the flue gas into the combustion zone to limit oxygen and peak temperatures; thus lowering NOx levels. Currently, FGR is the only technology available for reducing NOx emission from forced-draft burners. Manufacturers refer to the addition of external recirculation equipment to an existing unit as FGR. Replacement burners with internal or built-in flue gas recirculation capability are referred to as low-NOX burners.

The District has a demonstration project involving six atmospheric boilers that have been retrofit with low-NOX burners. Through this project there is documentation showing the emission limits in the rule can be achieved. Also, the heat input rating of each new burner is 13.4 percent below the heat input rating of the replaced burner. This is graphic evidence of fuel savings that will provide a payback to the owner/operator.

Boiler Tune-up

Experience has shown that regular boiler tune-up will both reduce emissions from a boiler and increase boiler efficiency. Increasing efficiency decreases fuel consumption, providing a payback to the owner/operator. The required tune-up procedure is Attachment 1 to Rule 74.15.1. This method will not meet the emission limitations required by the rule; however, for the small user exempt from the emission limits, it does provide a way to help decrease air emissions and conserve fuel.

Clean Fuels

If an existing boiler is fired on a fuel other than natural gas, the cost of reducing emissions to the levels established in the rule can be significantly decreased by converting to natural gas, electricity, or heat pump.

Combination of Technologies

The technique or combination of NOx control techniques used will be determined by the owner of the affected equipment based on feasibility, performance, cost and schedule.

EMISSIONS

INVENTORY

Staff has identified about 175 boilers in the District with a gross heat input between I and 5 MMBtu per hour. These units currently emit approximately 96.25 tons of NOx per year.

ESTIMATED REDUCTIONS

As shown in Table 2, seventy six boilers, with emissions of approximately 79.42 tons per year, will require emission control in the form of either low-NOX burner or flue gas recirculation. The emission reduction for these units win be 81.5 percent or 64.73 tons per year. The other 99 units will require regular tune-ups. The emission reduction resulting from improved operation due to regular maintenance will be approximately 20.5 percent or 3.45 tons per year. The total emission reduction for small boilers will be 70.84 percent or 68.18 tons per year.

Table 2
Rule 74.15.1. Boilers, Steam Generators, and Process Heaters

Number of Units	Total Emissions (tons/year)	Controls Reduction (percent)	Tune-up Reduction (percent)	Total Reduction (tons/year)
76	79.42	81.5	N/A	64.73
99	16.83	N/A	20.5	3.45
175	96.25	67.25	3.72	68.18

COST-EFFECTIVENESS

Most affected units can be retrofitted using low-NOX burners to comply with the rule. It is estimated that this control equipment will cost $12,600 for an average atmospheric unit rated at 3.0 MMBtu per hour of heat input. The control equipment for an average forced-draft unit presently costs approximately $25,000.00. With the SCAQMD rule compliance date for small boilers rapidly approaching, the control equipment costs are expected to drop dramatically. Also, the Permit to Construct and initial source testing requirement would add a cost of $2,500.00 to the compliance cost. The final addition to the compliance cost is the biennial source test requirement which is $1,500 per source test or $750 per year. If fuel savings were not considered, the cost-effectiveness would be $6,398.66 per ton ($3.20 per pound) of NOx reduced. In the worst case scenario, where an affected unit would be retrofit using FGR, the cost-effectiveness will be $80,754.14 per ton ($40.38 per pound) of NOx reduced. However, there is nothing in the rule requiring the use of flue gas recirculation. Therefore, the choice of using this most expensive method of rule compliance would be the owner's.

When fuel savings are considered, the overall cost-effectiveness of all emission reduction requirements proposed in Rule 74.15.1 is estimated to vary between a savings of $5,775.07 per ton (savings of $2.89 per pound) of NOx reduced and a cost of $21,060.16 per ton ($10.53 per pound) of NOx reduced depending on fuel consumption and the control method chosen.

EMISSION CONTROL COSTS

Costs associated with the retrofit of boilers and heaters to meet the requirements of Rule 74.15.1 are outlined below. Costs for retrofitting boilers are considered for low-NOX burners and flue gas recirculation (FGR). Detailed cost calculations are presented in Attachment C.

Low-NOX Burner

Since the low-NOX burner can include a reduction in fuel consumption, the cost or savings is dependent on fuel savings.

Based strictly on capital expenditure for a new burner with a ten percent loan amortized over ten years, the annual cost for a burner retrofit on a 3.0 MMBtu unit is $2,474.16. To determine cost per ton of emission reduction, assumptions of operating hours/fuel consumption must be made and the cost of compliance testing must be added. A ten percent duty cycle (876 operating hours) would be very low for a boiler; therefore, assuming a ten percent duty cycle should provide worse case cost data.

Assuming 876 operating hours, electricity cost would be $19.97 per year, fuel savings would be $2,095.30, and NOx reduction would be 502.76 pounds or 0.2514 tons. The annualized cost is $880.67 and the cost-effectiveness is $3,503.06 per ton ($1.75 per pound) of NOx reduced.

If that same unit were operated on a thirty eight percent duty cycle (10 x 10^9 Btu per year), the fuel savings is $7,973.00 per year and the cost-effectiveness is a savings of $5,775.07 per ton (savings of $2.89 per pound) of NOx reduced.

Flue Gas Recirculation (FGR)

Current control technology for forced-draft burners uses some form of FGR. The addition of a separate FGR system on a small boiler is not cost effective; however, new low-NOX forced-draft burners using internal FGR are cost effective.

The average annualized cost is $6,964.91 per year, which equates to a cost-effectiveness of $14,013.74 per ton ($7.01 per pound) of NOx reduced. There would be ten percent fuel savings with a low-NOX burner using internal flue gas recirculation.

SOCIOECONOMIC IMPACTS

Assembly Bill 2061 (Polanco), which became effective January 1, 1992, requires that the District Board consider the Socioeconomic impacts of any new rule or amendments to existing rules if air quality or emission limits are affected.

The Board must evaluate the following socioeconomic information on Rule 74.15.1.

(1) The type of industries or businesses, including small business, affected by the rule or regulation.

Affected industries include agriculture, mining, construction, manufacturing, non-manufacturing, and government. The sector affected most in terms of number of units, is educational services (SIC 82) with approximately 24 percent of these units. Commercial properties (SIC 65), the second largest affected sector, makes up 10 percent. The rest are spread among a large number of sectors in the economy. Approximately 20 percent of the affected units are owned by small businesses as defined by the Small Business Administration.

(2) *The impact of the rule or regulation on employment and the economy of the region affected by the adoption of the rule or regulation.*

The adoption of Rule 74.15.1 is not expected to have a negative impact on either employment or the economy of Ventura. By taking advantage of low interest rate loans available through the California Energy Commission and choosing the option of installing a low-NOX burner, business owners and operators can realize a savings as a result of complying with the rule.

All cost calculations for atmospheric burners have used a fuel savings of 13.4 percent. Actual experience has been that fuel savings average 20 percent. If the 20 percent factor is used, it can be demonstrated that every owner/operator of a unit with an atmospheric burner, required to meet the emission limits, will realize a savings.

(3) The range of probable costs, including costs to industry or business, including small business, of the rule or regulation.

Assuming a business owner or operator would choose the most cost-effective option, the cost of emission reduction requirements proposed in Rule *74.15.1 is* estimated to vary between a cost of $21,060.16 per ton *($10.53* per pound) of NOx reduced to a savings of *$5,775.07* per ton *($2.89* per pound) of NOx reduced depending on fuel consumption.

Should a business owner or operator choose to use flue gas recirculation, the cost of emission reduction requirements proposed in Rule 74.15.1 is estimated to vary between $14,013.74 to $42,757.49 per ton *($7.01* to $21.38 per pound) of NOx reduced depending on fuel consumption.

(4) *The availability and cost-effectiveness of alternatives to the rule or regulation being proposed or amended.*

There are no alternative controls currently available; however, the District could choose the option of requiring semiannual tune-ups in lieu of implementing NOx emission limits.

The application of emission limits on small boilers, steam generators, and process heaters is relatively recent. There has been neither time nor, with the development of burners that provide a payback to the owner/operator, incentive for development of alternate technologies. The application of flue gas recirculation is simply a technique adapted from large power plant boilers.

Semiannual tune-ups, which would result in an emission reduction of 20.5% or 19.73 tons per year and a small fuel savings of approximately 2%, would not provide the NOx emission reduction necessary to meet the goals established in the 1991 Air Quality Management Plan. Therefore, this option should be available only for those small users for whom the application of control technology cannot be shown to be cost-effective.

(5) The emission reduction potential of the rule or regulation.

The emission reduction from 76 controlled units will be about 0.1773 tons of NOx per day plus an additional 0.0095 tons of NOx per day emission reduction due to semiannual tune-ups imposed on the remaining 99 units. Total reductions resulting from implementation of all rule requirements will be 68.18 tons of NOx per year.

(6) *The necessity of adopting, amending, or repealing the rule or regulation in order to attain state and federal ambient air* standards pursuant *to Chapter 10 (commencing with Section 40910).*

Ventura County is classified as a severe nonattainment area for both Federal and California Ambient Air Quality Standards for ozone. The 1991 AQMP does not project attainment of the California ozone standard; however, the plan, if all projected control measures such as N-105 are implemented, does meet initial planning requirements of the California Clean Air Act and will continue the trend toward dean air. This rule adoption is an important part of the plan and will help the District in its effort to attain the standards.

IMPACTS

There are about 175 impacted units that are located in the Ventura County. Approximately 76 of these units will be required to meet the emission limits established in the rule. The remaining units will be exempted by the small user exemption.

DIRECT ECONOMIC IMPACTS

Exemption

The rule exempts units with an annual heat input of less than 1.8 x 10^9 Btu from the 30 ppmv NOx limit. Owners of units can receive this exemption by installing a non-resettable totalizing fuel meter for each fuel on all of the individual boilers. A non-resettable totalizing fuel meter typically costs approximately $1,800 each. Unit owners operating near the exemption level may choose to install low-NOX equipment instead of fuel meters to avoid the risk of incurring additional cost of installing the NOx equipment in the future if gas use exceeds the exemption level. The exempt units must tune-up at least annually or meet the 30 ppmv NOx limit.

There will be a few units with an annual heat input of less than 0.3 x 10^9 Btu exempted from both the 30 ppmv emission limit and the tune-up requirement. These units will be required to comply with rule requirements if annual heat input equals or exceeds 0.3 x 10^9 Btu in any rolling twelve month calendar period.

The heating capacity of many boilers is much greater than is necessary to meet the heating demands. An option available to the owner/ operator would be to have the boiler derated as defined in Section G of the rule.

At least 99 boilers could be eligible for the low fuel use exemption, based on the average 1989 gas usage in each industry. These units generally belong to facilities using units primarily for heating or are operating under capacity.

For many sectors, such as educational services, most units may be exempt from all but the meter installation and tune-up requirements because of low fuel usage. For example, the educational services sector consumes on average less than 1.8 x 10^9 Btu per year; therefore, the many of these boilers will be exempt from the 30 ppmv NOx requirement.

Replacement

Some existing units, which are nearing the end of their useful life, will be replaced as part of the compliance plan. A unit with complying low-NOX burners is similar in cost to the older style units; therefore, the rule would place no economic burden on the owners of these units. Additionally, the average unit, which does not meet the 30 ppmv NOx requirement, will be at least half way into the ten year life of a burner. Therefore, when the rule is fully implemented, most existing units, either the entire boiler or the burner, will be almost completely depreciated, and ready for replacement.

BACT Regulations

When the District does not have a rule for limiting emissions from an emissions unit and a request for an Authority to Construct is received, the applicable South Coast AQMD Rule, if available, is used for establishing emission limits for the new or modified emissions unit. A small number of new units have been installed using the South Coast AQMD Rule 1146.1 as BACT These units will have a NOx emission control cost of zero because they have already met the 30 ppmv limit. As a result, the overall control costs of the rule should be lower than estimated.

Conclusions

About 175 impacted units are in the County. Affected sectors include agriculture, in' i construction, manufacturing, non-manufacturing, and government. A low fuel use exemption specified in the rule is available to about 99 of these units. Recent BACT regulations already apply to a number new units. Both of these factors minimize the socioeconomic impact of the rule.

ENVIRONMENTAL IMPACTS

Introduction

Oxides of nitrogen (NOx) is a term used to collectively refer to nitric oxide (NO) and nitrogen dioxide (NO2). Most NO emissions react rapidly in the atmosphere to form N02.

Air quality in the Ventura County is significantly impacted by NOx emissions, since they directly or indirectly affect nitrogen dioxide (NO2), inhalable particulate (PM10), and ozone concentrations. Furthermore, the N02 and PM10 formed from NOx emissions decrease visibility and lead to nitric acid deposition. Concerns have also been expressed about the potential adverse health effects of other nitrogen compounds, such as nitroarenes and nitrosarnines, that result from NOx emissions.

District staff has concluded from the NOx related air quality literature that further reduction in NOx emissions will result in a net improvement in air quality. Emission inventory and air quality monitoring data for Ventura County show that NOx emissions must be substantially reduced if the District is to achieve the California ozone standards. Rule 74.15.1 is part of continuing efforts in the County to reduce ozone precursors thereby reducing concentrations of ROC, NOx, and other air pollutants.

Secondary Impacts

The following analysis discusses potential secondary environmental impacts that may result

from adopting the rule. All equipment subject to the rule would have to be in compliance with all rule requirements by May 31, 1995. Owner/Operators are expected to comply with the requirements of the rule primarily through equipment modifications and maintenance procedures, which include: boiler tune-up; stack excess oxygen control; low-NOX burners; flue gas recirculation (FGR); electric heating; or a combination of the above techniques. Since compliance with the rule is expected to be primarily through equipment modification or equipment maintenance techniques rather than by installing additional add-on control equipment, few secondary environmental impacts and no cross media impacts are expected. Even those secondary environmental impacts are either not significant or can be reduced to insignificance through mitigation measures.

Potential adverse environmental impacts are considered to exist in only two areas, risk of upset and human health.

Risk of Upset

Flue gas recirculation (FGR), affects flame temperature by diluting combustion air with flue gas that is low in oxygen content. The net result of FGR is that thermal NOx production declines, but the flammability range of the resulting flue gas, combustion air, and fuel mixture narrows considerably. As the percentage of flue gas increases, the percentage of oxygen necessary to sustain combustion may decrease to the point where the flame is extinguished. This creates flame instability that can increase the possibility of explosion. If enough unburned fuel is vented into the furnace and sufficient oxygen is present, an explosion can occur.

In general, FGR is inherently safe, but accidents can occur if equipment is not operated properly. To reduce the possibility of explosions when using FGR, equipment modifications should be made according to the equipment manufacturer's design and operating specifications. In addition, the following mitigation measures are recommended. First, the percentage of flue gas should never reach unstable conditions. This can be accomplished by controlling the flue gas concentration by monitoring the firing rate so that less flue gas is recirculated when the firing rate approaches unstable conditions. Second, properly mixing flue gas with combustion air reduces the probability of generating unstable conditions. Third, improper maintenance of the burner itself may contribute to unstable conditions. Therefore, the burner should undergo periodic routine maintenance.

Another technique of monitoring flame stability requires monitoring CO levels. By lowering the flame temperature, FGR not only reduces thermal NOx formation but it increases formation of products of incomplete combustion such as CO. However, by ensuring that CO levels are below the 400 ppmv limit (at all firing rates) specified by the rule, burner instability and, therefore, flame instability will be reduced.

In addition, insurance companies generally require boilers be equipped with flame sensors as part of the basic equipment. In the event that flame instability occurs and the flame is extinguished, flame sensors automatically shut off the combustion gas supply to the boiler, thus eliminating the conditions where an explosion could occur.

Alternatively, the owner/operator could use low-NOX burners instead of FGR and avoid the problem altogether. State of the art low-NOX burners exist that will bring affected equipment into compliance with the rule without using FGR. However, if the low-NOX burner cannot reduce emissions to less than 30 ppm, recirculation of small amounts of flue gas (no more than five percent, or according to manufacturers specifications) can reduce NOx emissions to less than 30 ppm.

In the past, problems have been reported regarding the safety of radiant ceramic burners. The primary concern was that ceramic burners were sensitive to minor changes in operating conditions, resulting in cracks in the ceramic material. Combustion gas could then escape from these cracks, creating conditions where an explosion could occur.

Because of past problems with radiant ceramic burner materials, manufacturers use newly developed materials that do not flash back when operated off specification. These new materials, coupled with proper ignition and flame controls, have improved radiant ceramic burner safety so that they are considered to be as safe as more traditional flame burners. The safety record of radiant ceramic burners has improved to the point where they are approved by AGA and UL and are accepted by major industrial insurers, such as Industrial Risk Insurers and Factory Mutual.

Finally, any boiler steam generator, or process heater modification should be performed pursuant to applicable safety and fire protection rules, regulations and standards issued by local, state, or federal agencies. Additional safety precautions include adhering to industry standards whenever these are available. Ensuring proper FGR operating procedures, using low-NOX burners, and complying with all applicable safety laws and regulations will reduce potential risks of explosion to insignificant levels.

Human Health

One of several options owner/operators have for complying with the requirements of the rule is using radiant burners. However, radiant burners may create significant adverse worker health impacts. Radiant burners contain ceramic fibers that may be released into the work place at a rate that may adversely affect worker health. Ceramic fibers are a health concern largely because of their structural similarity to asbestos. There is no human data available on the chronic effects of exposure to ceramic fibers. Like asbestos, ceramic fibers have been associated with lung tumors and mesothelioma in laboratory animals. However, there have been no human studies investigating the carcinogenicity of ceramic fibers. The International Agency for Research on Cancer lists ceramic fibers as a Group 2B carcinogen -possibly carcinogenic in humans. The American Conference of Governmental Industrial Hygienists has recommended a worker exposure limit of 2 fibers/cc for ceramic fibers, which is also its limit for asbestos. The scientific basis for this standard is limited.

The ceramic fibers in radiant burners are chemically bound in a bonded ceramic structure that greatly reduces the likelihood of fibers escaping from the device. Two independent tests of the rate of release of ceramic fibers from radiant burners (one test conducted by a radiant burner manufacturer and one conducted by the University of Missouri) both found that release of ceramic fibers from radiant burners were typically 2 – 4 orders of magnitude less than the 2 fiber/cc level. The relatively close measurements obtained from two independent tests, both of which were at least two orders of magnitude below the 2 fibers/cc air level, provide a reasonable margin of safety.

To further reduce potential exposure to ceramic fibers from radiant burners, the Carborundum Company recommends the following safety precautions:

- Provide engineering controls, where feasible, to keep airborne fiber exposure at the lowest level attainable.
- Use a NIOSH or MSHA approved air purifying respirator (3M 8710 or equivalent during installation and removal of products used at high temperatures. For airborne concentrations > 5 fibers/cc of air, consult the product MSDS for additional information.
- Wear long sleeved clothing, gloves, hat, and eye protection to prevent skin and eye contact. Wash thoroughly after handling.
- Avoid taking unwashed work clothes home or provide disposable work clothing. Wash work clothes separately from other clothing. Rinse washing machine thoroughly after use.

Because of the low potential for natural escape of fibers from ceramic burners, potential adverse human health effects from ceramic fibers are not considered to be significant. Potential adverse health impacts can be reduced even further using the above safety precautions and the safety precautions recommended on the MSDS for ceramic fibers.

REFERENCES

1. Staff Report, "Hearing on Controls of Oxides of Nitrogen (NOx)," SCAQMD, February 1986.

2. "Guidelines for Industrial Boiler Performance Improvement," McElroy, M.W. et al, KV`B, Inc., for the U.S. EPA contract 68-02-1074, January 1977.

3. Staff Report "Suggested Control Measure for Controlling Emissions of Oxides of Nitrogen from Industrial, Institutional, and Commercial Boilers, Steam Generators, and Process Heaters," Issued by California Air Resources Board, Release date: August 14, 1987.

4. "Emission Control Technology for Industrial Boilers," edited by A E. Martin, published by Noyes Data Corporation, Park Ridge, New Jersey, 1981.

5. Staff Report, "Proposed Rule 46 - Emissions of Oxides of Nitrogen from Industrial Boilers, Steam Generators, and Process Heaters," SCAQMD, October 21, 1987.

6. Staff Report, "Proposed Rule 46.1 - Emissions of Oxides of Nitrogen from Industrial Boilers, Steam Generators, and Process Heaters," SCAOMD, August 17, 1990.

7. California Employment Development Department publication "Projections of Employment by Industry and Occupation," 1992.

8. "Air Pollution Engineering Manual," Environmental Protection Agency, Office of Air and Water Programs, Office of Air Quality Planning and Standards, Research Triangle Park, NC 27711, May 1973

9. "Cost quote for 2" and 3" fuel flow valve with totalizer," Jensen Instrument Company, Azuza, CA 91702, Nov 1992

10. "Cost quote for Burner Retrofit," VKES, Inc., Huntington Beach, CA 92649, Nov 1992

11. "Cost quote for Burner Retrofit," Alzeta. Corporation, Santa Clara, CA 95054, Nov 1992

12. "Cost quote for Flue Gas Recirculation on Fire tube Boiler," Quality Boiler, Cerritos, CA 90701, Feb 1992

13. "Cost quote for Burner Retrofit on Fire tube Boiler," OFCCO Constructors, Inc., Long Beach, CA 90809-3008, Sep 1992

14. "Cost quote for Burner Retrofit on Fire tube Boiler," Coast Boiler Works, Los Alamitos, CA 90720-2547, Sep 1992

VENTURA COUNTY 1991 AIR QUALITY MANAGEMENT PLAN

NOx CONTROL MEASURE

N-105 (N-27), BOILERS, STEAM GENERATORS, AND PROCESS HEATERS

This control measure will reduce NOx emissions from small boilers, steam generators, and process heaters (less than 5 MMBtu's per hour but greater than or equal to 1 MMBtu's per hour) at commercial, industrial, and institutional facilities by revising APCD Rule 74.15, Boilers, Steam Generators, and Process Heaters to require that such equipment meet a 30 ppmv NOx limit (at three percent oxygen).

Proposed Rule Revision Date:	10/31/92
Proposed Rule Revision Implementation Date:	10/31/93
APCD Rule:	74.15
Required Board Action:	Revision to Rule 74.15
Cost-effectiveness:	$4.58 - $18.10/pound
1987 Baseline NOx Emission Inventory:	1.54 tons/day
Control Efficiency:	40% overall
Total Emission Reduction:	0.63 tons/day

Note: Control measure N-27 from the 1987 AQMP was adopted as Rule 74.15, and controls NOx emissions from boilers, steam generators, and process heaters greater than or equal to 5 MMBtu's per hour. Control measure N-105 as it is proposed in the 1991 AQMP proposes to control emissions from boilers, steam generators, and process heaters less than 5 MMBtu's per hour.

AFFECTED INDUSTRIES

SIC#	Industry	SIC#	Industry
0	UNKNOWN INDUSTRY	52	BLDG MAT, HDW&M0 HM DL
01	AGR PROD - CROPS	53	GEN MDSE STORES
02	AGR PROD - LIVESTOCK	54	FOOD STORES
07	AGR SERVICES	55	AUTOMTV DL & GAS SV ST
13	OIL & GAS EXTRACTION	57	FURN/HM FURN & EQU STR
15	BLD CONS-GN CONT/OPR	58	EATING & DRINKING PL
16	CONS OTH THAN BLDG	59	MISCELLANEOUS RETAIL
17	CONST-SP TRADE CONTR	60	BANKING
20	FOOD & KINDRED PROD	61	CR AGCY OTH THN BANK
23	APPAREL & OTH FIN PROD	62	SEC & COM BR, DL, EXC & SV
24	LUMB & WD PROD EX FURN	63	INSURANCE
25	FURNITURE & FIXTURES	64	INS AGTS, BRKRS & SVC
26	PAPER & ALLIED PROD	65	REAL ESTATE
27	PRNTG, PUB & ALLIED PROD	67	HOLDNG & OTH INVES OFF
28	CHEMICAL & ALLIED PROD	70	HOT, RM HS, CMP/OT LOD
29	PETRO RFG & REL TD IND	72	PERSONAL SERVICES
30	RUBBER & MISC PLASTIC	73	BUSINESS SERVICES
32	STONE, CLAY, GLSS, CONC	75	AUTOMTV REP, SVC & GAR
33	PRIMARY METAL INDUS	76	MISC REPAIR SERVICES
34	FAB METAL X MAC & TRAN	80	HEALTH SERVICES
35	MACHINERY EXCPT ELEC	81	LEGAL SERVICES
36	ELEC & ELE MACH, EQ & SUP	82	EDUCATIONAL SERVICES
37	TRANSPORTATION EQUIP	83	SOCIAL SERVICES
38	MEAS, ANAL, CNTL INSTR	87	ENG & MTG SERVICES
39	MISC MFG INDUSTRIES	89	MISC SERVICES
42	MOTOR FRT TRANS & WHSE	91	EXEC, LEG & G GOV X FIN
47	TRANSPORTATION SVCS	92	JUSTICE, PU ORD & SAFTY
48	COMMUNICATION	94	ADM HUMAN RESOURCE PR
49	ELEC, GAS & SANIT SVCS	96	ADM OF ECONOMIC PROG
50	WHOL TRADE-DUR GOODS	97	NAT SEC & INI'L AFFAIRS
51	WHOL TRDE-NONDUR GDS	99	NONCLASSIFIBLE ESTAB

ATTACHMENT B

AIR POLLUTION CONTROL COST-EFFECTIVENESS CALCULATIONS

INTRODUCTION

Consider the current boiler, steam generator, and process heater population in the District ranging between 1 and 5 MMBtu per hour rated heat input capacity subject to Rule 74.15.1. Rule 74.15.1 specifies an exemption level of 1.8 x 10^9 Btu per year. Approximately 76 units will be required to meet a 30 ppm NOx emission limit at 3% 0_2.

The calculations for water tube boilers with atmospheric burners use the following assumptions:

- 10 Year Burner Life
- 10 Percent Annual Interest Rate
- Capital Recovery Factor (CRF) = 0.1586
- The new burner will be 13.4% smaller than the existing burner without increasing cycle time resulting in a fuel savings of 13.4 percent.
- Fuel consumption is equally split between summer rates and winter rates. Summer rate is $5.30 per MMBtu and winter rate is $6.60 per MMBtu.
- NOx reduction is from 160 ppm (02 pounds NOx per MMBtu heat input) to 30 ppm. (0.037 pounds NOx per MMBtu heat input) or a reduction of 130 ppm. (0.163 pounds NOx per MMBtu heat input)

The California Energy Commission will make five year, five percent loans to Small Businesses for energy conservation projects. The low-NOX burner used as the basis for the calculations on the atmospheric burners qualifies for these loans. The yearly cost for five years would be higher; however, over the projected ten year life of the burner, the business owner/operator would experience a significant positive payback on the investment.

The calculations for water tube boilers with forced-draft burners use the following assumptions:

- 10 Year Burner Life
- 10 Percent Annual Interest Rate
- Capital Recovery Factor (CRF) = 0.1586
- The new burner will result in a fuel savings of 10 percent.
- Fuel consumption is equally split between summer rates and winter rates. Summer rate is $0.53 per therm and winter rate is $0.66 per therm
- NOx reduction is from 80 ppm (0.1 pounds NOx per MMBtu heat input) to 30 ppm (0.037 pounds NOx per MMBtu heat input) or a reduction of 50 ppm (0.063 pounds NOx per MMBtu heat input)

The fuel savings used for both the atmospheric and forced-draft burners are below the savings resulting from practical experience with the burners. Also, it would be unusual for fuel consumption in the summer months to equal fuel consumption during the winter months. However, cost-effectiveness can be demonstrated using these figures and a "margin for error" is built into the calculations.

The calculations for fire tube boilers use the following assumptions:

- 10 Year Burner Life
- 10 Percent Annual Interest Rate
- The smallest unit is 50 Horsepower or 2 MMBtu.
- Fire tube boilers are normally used as process heaters and are high use units (3,500 hours per year is used)
- Capital Recovery Factor (CRF) = 0.1586
- The new burner will result in a fuel savings of 10 percent
- There would be no fuel savings if external flue gas recirculation is added
- Fuel consumption is equally split between summer rates and winter rates

- Summer rate is $0.53 per therm and winter rate is $0.66 per therm
- NOx reduction is from 80 ppm (0.1 pounds NOx per MMBtu heat input) to 30 ppm (0.037 pounds NOx per MMBtu heat input) or a reduction of 50 ppm (0.063 pounds NOx per MMBtu heat input)

Discussions with industry representatives indicate fuel consumption decreases by 10% if a new burner using internal flue gas recirculation is installed. If external flue gas recirculation equipment is installed, there would be no fuel savings guaranteed.

It would be unusual for fuel consumption in the summer months to equal fuel consumption during the winter months. However, cost-effectiveness can be demonstrated using these figures and a "margin for error" is built into the calculations.

CALCULATIONS

CASE 1: LOW-NOX BURNER RETROFIT - ATMOSPHERIC BURNER

Parameters

An atmospheric unit with a rated heat input capacity of 3.0 MMBtu per hour and annual heat input of 5.5 x 10^9 Btu retrofitted with a low-NOX burner rated at 2.6 MMBtu to reduce NOx emissions from 160 ppm to 30 ppm. The unit operates 1,833 hours per year.

Costs

Annualized capital cost:
Estimated capitol cost including installation: $12,600.00
Cost for source test and permit: $3,000.00
(0.1586 X $15,600.00) = $2,474.16
Annualized cost for source test = 750.00
Biennial source test $1,500.00
Annualized operating cost (electric power for fan)
((1833 hours/year) x (0.3 kw) x ($0.076/kw-hour) = $41.79
Fuel Savings: ((2.75 x 10^9 Btu) x 13.4 % x ($0.53/$10^5$ Btu)) = $1,953.05
+ ((2.75 x 10^9 Btu) x 13.4 % x ($0.66/$10^5$ Btu)) = $2,432.10
((5.50 x 10^9 Btu) x 13.4 % x ($0.595/$10^5$ Btu)) = (4,385.15)
Total annualized cost: $2,474.16 + $750.00 + $41.79 - $4,385.15 = $(1,103.99)

NOx Emission Reduction

((4.763 x 10^9 Btu)/year) x ((0.167 pounds NOx)/10^6 Btu) = 776.37 pounds NOx/year
((0.737 x 10^9 Btu)/year) x ((0.200 pounds NOx)/10^6 Btu) = 120.13 pounds NOx/year
= 0.4483 tons NOx/year

Cost-effectiveness

The rule cost-effectiveness (C.E.) using low-NOX burners is:
C.E. = ($/year)/(tons NOx/year)
= $/ton NOx = $1,103.99/0.4483 tons NOx Reduced (savings)
= $2,462.61/ton NOx Reduced (savings)
= $1.23/pound NOx Reduced (savings)

CALCULATIONS

CASE 2: LOW-NOX BURNER RETROFIT TECHNOLOGY - ATMOSPHERIC BURNER

Parameters

An atmospheric unit with a rated heat input capacity of 3.0 MMBtu per hour and annual heat input of 2.4 x 10^9 Btu retrofitted with a low-NOX burner. The unit operates 800 hours per year. The NOx emissions are reduced from 160 ppm to 30 ppm.

Costs

Annualized capital cost:
Estimated capitol cost including installation: $12,600.00
Cost for source test and permit: $3,000.00
(0.1586 X $15,600.00) = $2,474.16
Annualized cost for source test = 750.00
Biennial source test $1,500.00
Annualized operating cost (electric power for fan)
((800 hours/year) x (0.3 kw) x ($0.076/kw-hour) = $18.24
Fuel Savings: ((1.2 x 10^9 Btu) x 13.4 % x ($0.53/$10^5$ Btu)) = $852.24
+ ((1.2 x 10^9 Btu) x 13.4 % x ($0.66/$10^5$ Btu)) = $1,061.28
((2.40 x 10^9 Btu) x 13.4 % x ($0.595/$10^5$ Btu)) = (1,913.52)
Total annualized cost: $2,474.16 + $750.00 + $18.24 - $1,913.52 = $1,328.88)

NOx Emission Reduction

((2.0784 x 10^9 Btu)/year) x ((0.167 pounds NOx)/10^6 Btu) = 339.00 pounds NOx/year
((0.3216 x 10^9 Btu)/year) x ((0.200 pounds NOx)/10^6 Btu) = 64.00 pounds NOx/year
= 0.202 tons NOx/year

Cost-effectiveness

The rule cost-effectiveness (C.E.) using low-NOX burners is:
C.E. = ($/year)/(tons NOx/year)
= $/ton NOx = $1,328.88/0.202 tons NOx Reduced
= $6,578.61/ton NOx Reduced
= $3.29/pound NOx Reduced

CALCULATIONS

CASE 3: LOW-NOX BURNER RETROFIT - ATMOSPHERIC BURNER

Parameters

An atmospheric unit with a rated heat input capacity of 1.15 MMBtu per hour (1.15 MMBtu is used because the new burner for any smaller unit would be below 1 MMBtu and thus exempt from the rule) and annual heat input of 2.07 x 10^9 Btu is retrofitted with a low-NOX burner. The NOx emissions are reduced from 160 ppm to 30 ppm. The unit operates 1,800 hours per year.

Costs

Annualized capital cost:			
Estimated capitol cost including installation:	$5,520.00		
Cost for source test and permit:	$3,000.00		
(0.1586 X $8,520.00)			= $1,351.27
Annualized cost for source test			= 750.00
Biennial source test $1,500.00			
Annualized operating cost (electric power for fan)			
((1800 hours/year) x (0.3 kw) x ($0.076/kw-hour)			= $41.04
Fuel Savings:	((1.035 x 10^9 Btu) x 13.4 % x ($0.53/$10^5$ Btu))	= $735.06	
	+ ((1.035 x 10^9 Btu) x 13.4 % x ($0.66/$10^5$ Btu))	= $915.35	
	((2.07 x 10^9 Btu) x 13.4 % x ($0.595/$10^5$ Btu))		= (1,650.41)
Total annualized cost:	$1,351.27 + $750.00 + $41.04 - $1,650.41 =		$491.90

NOx Emission Reduction

((1.80 x 10^9 Btu)/year) x ((0.167 pounds NOx)/10^6 Btu) = 300.60 pounds NOx/year
((0.27 x 10^9 Btu)/year) x ((0.200 pounds NOx)/10^6 Btu) = 54.00 pounds NOx/year
= 0.1773 tons NOx/year

Cost-effectiveness

The rule cost-effectiveness (C.E.) using low-NOX burners is:

C.E. = ($/year)/(tons NOx/year)
= $/ton NOx = $491.90/0.1773 tons NOx Reduced
= $2,774.40/ton NOx Reduced
= $1. 39/pound NOx Reduced

CALCULATIONS

CASE 4: LOW-NOX BURNER RETROFIT TECHNOLOGY - ATMOSPHERIC BURNER

Parameters

An atmospheric unit with a rated heat input capacity of 1 MMBtu per hour and annual heat input of 1.8 x 10^9 Btu is retrofitted with a low-NOX burner. The NOx emissions are reduced from 160 ppm to 30 ppm. The unit operates 1,800 hours per year. The new burner, 0.866 MMBtu would be exempt; therefore the biennial source test would not be required.

Costs

Annualized capital cost:
Estimated capitol cost including installation: $5,520.00
Cost for source test and permit: $3,000.00
(0.1586 X $8,520.00) = $1,351.27
Annualized operating cost (electric power for fan)
((1,800 hours/year) x (0.3 kw) x ($0.076/kw-hour) = $41.04
Fuel Savings: ((0.9 x 10^9 Btu) x 13.4 % x ($0.53/$10^5$ Btu)) = $639.18
<u>+ ((0.9 x 10^9 Btu) x 13.4 % x ($0.66/$10^5$ Btu))</u> = $795.96
((1.80 x 10^9 Btu) x 13.4 % x ($0.595/$10^5$ Btu)) = <u>(1,435.14)</u>
Total annualized cost: $1,351.27 + $41.04 - $1,435.14 = $(42.83)

NOx Emission Reduction

((1.5588 x 10^9 Btu)/year) x ((0.167 pounds NOx)/10^6 Btu) = 260.32 pounds NOx/year
((0.2412 x 10^9 Btu)/year) x ((0.200 pounds NOx)/10^6 Btu) = 48.24 pounds NOx/year
= 0.1543 tons NOx/year

Cost-effectiveness

The rule cost-effectiveness (C.E.) using low-NOX burners is:
C.E. = ($/year)/(tons NOx/year)
= $/ton NOx = $42.83/0.1543 tons NOx Reduced (savings)
= $277.58/ton NOx Reduced (savings)
= $0.14/pound NOx Reduced (savings)

CALCULATIONS

CASE 5: LOW-NOX BURNER RETROFIT - ATMOSPHERIC BURNER

Parameters

An atmospheric unit with a rated heat input capacity of 1 MMBtu per hour and annual heat input of 1.8 x 10^9 Btu is retrofitted with a low-NOX burner. The NOx emissions are reduced from 160 ppm to 30 ppm. The unit operates 1,800 hours per year. The new burner, 0.866 MMBtu would be exempt; therefore the biennial source test would not be required. Also, the owner has gotten a 5% - 5 year loan.

Costs

Annualized capital cost:
Estimated capitol cost including installation: $5,520.00
Cost for source test and permit: $3,000.00
(0.2265 X $8,520.00) = $1,929.78
Annualized operating cost (electric power for fan)
((1,800 hours/year) x (0.3 kw) x ($0.076/kw-hour) = $41.04
Fuel Savings: ((0.9 x 10^9 Btu) x 13.4 % x ($0.53/$10^5$ Btu)) = $639.18
+ ((0.9 x 10^9 Btu) x 13.4 % x ($0.66/$10^5$ Btu)) = $795.96
((1.80 x 10^9 Btu) x 13.4 % x ($0.595/$10^5$ Btu)) = (1,435.14)
Total annualized cost: $1,351.27 + $41.04 - $1,435.14 = $535.68

NOx Emission Reduction

((1.5588 x 10^9 Btu)/year) x ((0.167 pounds NOx)/10^6 Btu) = 260.32 pounds NOx/year
((0.2412 x 10^9 Btu)/year) x ((0.200 pounds NOx)/10^6 Btu) = 48.24 pounds NOx/year
= 0.1543 tons NOx/year

Cost-effectiveness

The rule cost-effectiveness (C.E.) using low-NOX burners is:
C.E. = ($/year)/(tons NOx/year)
= $/ton NOx = $535.68/0.1543 tons NOx Reduced
= $3,471.68/ton NOx Reduced
= $1.74/pound NOx Reduced

CALCULATIONS

CASE 6: LOW-NOX BURNER RETROFIT TECHNOLOGY – FORCED-DRAFT BURNER

Parameters

A unit with a rated heat input capacity of 3.0 MMBtu per hour and annual heat input of 7.5 x 10^9 Btu retrofit with a low-NOX burner using internal flue gas recirculation to reduce NOx emissions from 80 ppm to 30 ppm. The unit operates 2,500 hours per year.

Costs

Annualized capital cost:			
Estimated capitol cost including installation:	$25,000.00		
Cost for source test and permit:	$3,000.00		
(0.1586 X $28,000.00)			= $4,440.80
Annualized cost for source test			= 750.00
Biennial source test $1,500.00			
Fuel Savings:	((3.75 x 10^9 Btu) x 13.4 % x ($0.53/$10^5$ Btu))	= $1,987.50	
	+ ((3.75 x 10^9 Btu) x 13.4 % x ($0.66/$10^5$ Btu))	= $2,475.00	
	((7.50 x 10^9 Btu) x 13.4 % x ($0.595/$10^5$ Btu))		= (4,462.50)
Total annualized cost:	$4,440.80 + $750.00 - $4,462.50 =		$728.30

NOx Emission Reduction

((6.75 x 10^9 Btu)/year) x ((0.063 pounds NOx)/10^6 Btu)	= 425.25 pounds NOx/year
((0.75 x 10^9 Btu)/year) x ((0.10 pounds NOx)/10^6 Btu)	= 75.00 pounds NOx/year
	= 0.2501 tons NOx/year

Cost-effectiveness

The rule cost-effectiveness (C.E.) using low-NOX burners is:

C.E. = ($/year)/(tons NOx/year)
= $/ton NOx = $728.30/0.2501 tons NOx Reduced
= $2,912.04/ton NOx Reduced
= $1.46/pound NOx Reduced

CALCULATIONS

CASE 7: LOW-NOX BURNER RETROFIT – FORCED-DRAFT BURNER

Parameters

A unit with a rated heat input capacity of 3.0 MMBtu per hour and annual heat input of 5.5 x 10^9 Btu retrofit with a low-NOX burner using internal flue gas recirculation to reduce NOx emissions from 80 ppm to 30 ppm. The unit operates 1,833 hours per year.

Costs

Annualized capital cost:
Estimated capitol cost including installation: $25,000.00
Cost for source test and permit: $3,000.00
(0.1586 X $28,000.00) = $4,440.80
Annualized cost for source test = 750.00
Biennial source test $1,500.00
Fuel Savings: ((2.75 x 10^9 Btu) x 13.4 % x ($0.53/$10^5$ Btu)) = $1,457.50
+ ((2.75 x 10^9 Btu) x 13.4 % x ($0.66/$10^5$ Btu)) = $1,815.00
((5.50 x 10^9 Btu) x 13.4 % x ($0.595/$10^5$ Btu)) = (3,272.50)
Total annualized cost: $4,440.80 + $750.00 - $3,272.50 = $1,918.30

NOx Emission Reduction

((4.95 x 10^9 Btu)/year) x ((0.063 pounds NOx)/10^6 Btu) = 311.85 pounds NOx/year
((0.55 x 10^9 Btu)/year) x ((0.10 pounds NOx)/10^6 Btu) = 55.00 pounds NOx/year
= 0.1834 tons NOx/year

Cost-effectiveness

The rule cost-effectiveness (C.E.) using low-NOX burners is:
C.E. = ($/year)/(tons NOx/year)
= $/ton NOx = $1,918.30/0.1834 tons NOx Reduced
= $10,459.65/ton NOx Reduced
= $5.23/pound NOx Reduced

CALCULATIONS

CASE 8: FLUE GAS RECIRCULATION (FGR) - FORCED-DRAFT BURNER

Parameters

A unit with a rated heat input capacity of 3.0 MMBtu per hour and annual heat input of 5.5 x 10^9 Btu retrofit with external flue gas recirculation (FGR) to reduce NOx emissions from 80 ppm to 30 ppm. The unit operates 1,833 hours per year.

Costs

Annualized capital cost:		
Estimated capitol cost including installation:	$25,000.00	
Cost for source test and permit:	$3,000.00	
(0.1586 X $28,000.00)		= $4,440.80
Annualized cost for source test		= 750.00
Biennial source test $1,500.00		
Annualized operating cost (electric power for fan)		
5 HP x (0.746 kw-hour/HP) x ($0.076/kw-hour) x (1,833 hours/year)		= $519.62
Total annualized cost: $4,440.80 + $750.00 + $519.62 =		$5,710.42

NOx Emission Reduction

(5.5 x 10^9 Btu)/year) x ((0.063 pounds NOx)/10^6 Btu) = 346.5 pounds NOx/year
= 0.1733 tons NOx/year

Cost-effectiveness

The rule cost-effectiveness (C.E.) using low-NOX burners is:

C.E. = ($/year)/(tons NOx/year)
= $/ton NOx = $5,710.40/0.1733 tons NOx Reduced
= $32,951.07/ton NOx Reduced
= $16.48/pound NOx Reduced

CALCULATIONS

CASE 9: FLUE GAS RECIRCULATION (FGR) - FORCED-DRAFT BURNER

Parameters

A unit with a rated heat input capacity of 2.0 MMBtu per hour and annual heat input of 1.8 x 10^9 Btu retrofit with external flue gas recirculation (FGR) to reduce NOx emissions from 80 ppm to 30 ppm. The unit operates 900 hours per year.

Costs

Annualized capital cost:		
Estimated capitol cost including installation:	$25,000.00	
Cost for source test and permit:	$3,000.00	
(0.1586 X $28,000.00)		= $4,440.80
Annualized cost for source test		= 750.00
Biennial source test $1,500.00		
Annualized operating cost (electric power for fan)		
5 HP x (0.746 kw-hour/HP) x ($0.076/kw-hour) x (1,800 hours/year)		= <u>$510.26</u>
Total annualized cost: $4,440.80 + $750.00 + $510.23 =		$5,701.06

NOx Emission Reduction

(1.8 x 10^9 Btu)/year) x ((0.063 pounds NOx)/10^6 Btu) = 113.4 pounds NOx/year
= 0.0567 tons NOx/year

Cost-effectiveness

The rule cost-effectiveness (C.E.) using low-NOX burners is:

C.E. = ($/year)/(tons NOx/year)
= $/ton NOx = $5,701.06/0.0567 tons NOx Reduced
= $100,547.80/ton NOx Reduced
= $50.27/pound NOx Reduced

CALCULATIONS

CASE 10: LOW-NOX BURNER USING INTERNAL RECIRCULATION – FIRE TUBE BOILER

Parameters

A unit with a rated heat input capacity of 2.0 MMBtu per hour and annual heat input of 7.0 x 10^9 Btu retrofitted with a low-NOX burner using internal flue gas recirculation to reduce NOx emissions from 80 ppm to 30 ppm. The unit operates 3,500 hours per year.

Costs

Annualized capital cost:			
Estimated capitol cost including installation:	$27,500.00		
Cost for source test and permit:	$3,000.00		
(0.1586 X $30,500.00)			= $4,837.30
Annualized cost for source test			= 750.00
Biennial source test $1,500.00			
Annualized operating cost (electric power for fan)			
5 HP x (0.746 kw-hour/HP) x ($0.076/kw-hour) x (3,500 hours/year)			= $992.18
Fuel Savings:	((3.5 x 10^9 Btu) x 10 % x ($0.53/$10^5$ Btu))	= $1,855.00	
	+ ((3.5 x 10^9 Btu) x 10 % x ($0.66/$10^5$ Btu))	= $2,310.00	
	((7.0 x 10^9 Btu) x 10 % x ($0.595/$10^5$ Btu))		= (4,165.00)
Total annualized cost:	$4,837.30 + $750.00 + $992.18 - $4,165.00 =		$2,414.48

NOx Emission Reduction

((6.3 x 10^9 Btu)/year) x ((0.063 pounds NOx)/10^6 Btu) = 396.9 pounds NOx/year
((0.7 x 10^9 Btu)/year) x ((0.10 pounds NOx)/10^6 Btu) = 70.00 pounds NOx/year
= 0.2335 tons NOx/year

Cost-effectiveness

The rule cost-effectiveness (C.E.) using low-NOX burners is:

C.E. = ($/year)/(tons NOx/year)
= $/ton NOx = $2,414.48/0.2335 tons NOx Reduced
= $10,340.39/ton NOx Reduced
= $5.17/pound NOx Reduced

CALCULATIONS

CASE 11: LOW-NOX BURNER USING INTERNAL RECIRCULATION – FIRE TUBE BOILER

Parameters

A unit with a rated heat input capacity of 2.0 MMBtu per hour and annual heat input of 4.5 x 10^9 Btu retrofitted with a low-NOX burner using internal flue gas recirculation to reduce NOx emissions from 80 ppm to 30 ppm. The unit operates 2,250 hours per year.

Costs

Annualized capital cost:
Estimated capitol cost including installation: $25,000.00
Cost for source test and permit: $3,000.00
(0.1586 X $28,000.00) = $4,440.80
Annualized cost for source test = 750.00
Biennial source test $1,500.00
Annualized operating cost (electric power for fan)
5 HP x (0.746 kw-hour/HP) x ($0.076/kw-hour) x (2,250 hours/year) = $637.83
Fuel Savings: ((2.25 x 10^9 Btu) x 10 % x ($0.53/$10^5$ Btu)) = $1,192.50
+ ((2.25 x 10^9 Btu) x 10 % x ($0.66/$10^5$ Btu)) = $1,485.00
((4.5 x 10^9 Btu) x 10 % x ($0.595/$10^5$ Btu)) = (2,677.50)
Total annualized cost: $4,440.80 + $750.00 + $637.83 - $2,677.50 = $3,161.13

NOx Emission Reduction

((4.05 x 10^9 Btu)/year) x ((0.063 pounds NOx)/10^6 Btu) = 255.15 pounds NOx/year
((0.45 x 10^9 Btu)/year) x ((0.10 pounds NOx)/10^6 Btu) = 45.00 pounds NOx/year
= 0.1501 tons NOx/year

Cost-effectiveness

The rule cost-effectiveness (C.E.) using low-NOX burners is:
C.E. = ($/year)/(tons NOx/year)
= $/ton NOx = $3,161.13/0.1501 tons NOx Reduced
= $21,060.16/ton NOx Reduced
= $10.53/pound NOx Reduced

CALCULATIONS

CASE 12: LOW-NOX BURNER USING INTERNAL RECIRCULATION – FIRE TUBE BOILER

Parameters

A unit with a rated heat input capacity of 5.0 MMBtu per hour and annual heat input of 17.5 x 10^9 Btu retrofitted with a low-NOX burner using internal flue gas recirculation to reduce NOx emissions from 80 ppm to 30 ppm. The unit operates 3,500 hours per year.

Costs

Annualized capital cost:
Estimated capitol cost including installation: $37,500.00
Cost for source test and permit: $3,000.00
(0.1586 X $40,500.00) = $6,423.30
Annualized cost for source test = 750.00
Biennial source test $1,500.00
Annualized operating cost (electric power for fan)
5 HP x (0.746 kw-hour/HP) x ($0.076/kw-hour) x (3,500 hours/year) = $992.18
Fuel Savings: ((8.75 x 10^9 Btu) x 10 % x ($0.53/$10^5$ Btu)) = $4,637.50
+ ((8.75 x 10^9 Btu) x 10 % x ($0.66/$10^5$ Btu)) = $5,775.00
((17.5 x 10^9 Btu) x 10 % x ($0.595/$10^5$ Btu)) = ($10,412.50)
Total annualized cost: $6,423.30 + $750.00 + $992.18 - $10,412.50 = ($2,247.02)

NOx Emission Reduction

((15.75 x 10^9 Btu)/year) x ((0.063 pounds NOx)/10^6 Btu) = 992.25 pounds NOx/year
((1.75 x 10^9 Btu)/year) x ((0.10 pounds NOx)/10^6 Btu) = 175.00 pounds NOx/year
= 0.584 tons NOx/year

Cost-effectiveness

The rule cost-effectiveness (C.E.) using low-NOX burners is:
C.E. = ($/year)/(tons NOx/year)
= $/ton NOx = $2,247.02/0.584 tons NOx Reduced (savings)
= $3,847.64/ton NOx Reduced (savings)
= $1.92/pound NOx Reduced (savings)

CALCULATIONS

CASE 13: LOW-NOX BURNER RETROFIT - ATMOSPHERIC BURNER

Parameters

An atmospheric unit with a rated heat input capacity of 1.2 MMBtu per hour and annual heat input of 2.08 x 10^9 Btu retrofitted with a low-NOX burner rated at 1.04 MMBtu to reduce NOx emissions from 160 ppm to 30 ppm. The unit operates 1,735 hours per year.

Costs

Annualized capital cost:
Estimated capitol cost including installation: $10,000.00
Cost for source test and permit: $3,000.00
(0.1586 X $15,600.00) = $2,061.80
Annualized cost for source test = 750.00
Biennial source test $1,500.00
Annualized operating cost (electric power for fan)
((1735 hours/year) x (0.3 kw) x ($0.076/kw-hour) = $39.56
Fuel Savings: ((1.04 x 10^9 Btu) x 13.4 % x ($0.53/$10^5$ Btu)) = $738.61
+ ((1.04 x 10^9 Btu) x 13.4 % x ($0.66/$10^5$ Btu)) = $919.78
((2.08 x 10^9 Btu) x 13.4 % x ($0.595/$10^5$ Btu)) = (1,658.39)
Total annualized cost: $2,061.80 + $750.00 + $39.56 - $1,658.39 = $1,192.97

NOx Emission Reduction

((1.8 x 10^9 Btu)/year) x ((0.163 pounds NOx)/10^6 Btu) = 293.4 pounds NOx/year
((0.28 x 10^9 Btu)/year) x ((0.200 pounds NOx)/10^6 Btu) = 56 pounds NOx/year
= 0.1747 tons NOx/year

Cost-effectiveness

The rule cost-effectiveness (C.E.) using low-NOX burners is:
C.E. = ($/year)/(tons NOx/year)
= $/ton NOx = $1,192.97/0.1747 tons NOx Reduced
= $6,828.68/ton NOx Reduced
= $3.41/pound NOx Reduced